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Is per capita electricity consumption stationary? Time series evidence from OECD countries

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This study examines the stationary properties of per capita electricity consumption in which the endogenously determined break points are incorporated in 23 high income OECD countries by using annual data over 1960–2005 period. We utilize Lagrange Multiplier (LM) unit root test that endogenously determines structural breaks in level and/or trend. We find that 21 country series reject the unit root null hypothesis at the 5% significance level, except for 2 country series. Thus, our empirical findings provide significant evidence that per capita electricity consumption is stationary in almost all countries considered in the study. The stationarity of per capita electricity consumption indicates that it should be possible for the series to forecast future movements in the energy consumption based on the past behaviors of the series. Important policy implications emerge from our empirical results of the unit root test with multiple structural breaks.

Contents

1. Introduction

There is a growing body of the literature which investigates the stationarity of per capita energy consumption using a variety of methodologies such as Chen and Lee [1], Narayan and Smyth [2], Hsu et al. [3], Mishra et al. [4], Lean and Smyth [5], Apergis et al. [6], and Narayan et al. [7]. Investigating time series properties of per capita energy consumption is critical not only for researchers but also for the policymakers. In this regard, the presence of a unit root of per capita energy consumption will suggest that this series does not revert to its equilibrium level after being hit by a shock. If per capita energy consumption is a stationary process, then effect of the shock is transitory, and as a result, it is possible to forecast future movements in energy consumption based on the past behaviors of the series [4]. On the other hand, if energy consumption is a non-stationary process, then any shock to energy consumption is likely to be permanent [1].

Most of the previous literature about the stationarity and non-stationarity of energy consumption concluded that energy consumption is non-stationary when examining the properties of energy consumption without structural breaks (see Chen and Lee [1]). However, when structural breaks are taken into account, most of the studies show that energy consumption per capita is stationary. Thus, taking structural breaks in the energy consumption series will significantly increase the power of the unit root tests.

The previous studies mostly focus on the total energy consumption not on the forms of energy consumption and provide valuable insights into the time series properties of energy consumption. However, as it is known, electricity is one of the most dominant forms of energy in the world. Therefore, different from the previous studies, we consider electricity consumption instead of total energy consumption in this paper. For this reason, we apply univariate Lagrange Multiplier (LM) unit root tests with structural breaks for 23 OECD countries over the 1960–2005 period. The rest of the

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paper is organized as follows. Next section describes the methodology and the data. The empirical analysis is presented in Section 3. Section 4 concludes the paper.

2. Methodology and data

This paper applies univariate LM unit root tests with structural breaks in which proposed by Lee and Strazicich [8]. We utilized the most general model that allows us for up to two breaks in the level and trend of the series. According to the LM (score) principle, a unit root test statistics can be obtained from the following regression:

$$\Delta Y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{1}^{k} \gamma_i \Delta \tilde{S}_{t-i} + \varepsilon_t \qquad (1)$$

where $\tilde{S}_t$ de-trended series that $\tilde{S}_t = Yt - \tilde{\psi}_x - Z_t\tilde{\delta}$, for $t = 2, \ldots, T$. $\tilde{\delta}$ is a vector of coefficients estimated from the regression of ΔYt on ΔZt and $\tilde{\psi}_x = Y_1 - Z_1\tilde{\delta}$, where Y_1 and Z_1 are first observations of Y_t and Z_t, respectively. Z_t is a vector of exogenous variables defined by the data generation process of the series. The model includes two breaks in level and trend is described by $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$, where $D_{jt} = 1$ for $t \geq T_{bj} + 1$, $j = 1, 2$ and zero otherwise.

The unit root null hypothesis is described by $\phi = 0$ (implying a unit root with two breaks), and the LM test statistics are given by:

$$\tilde{\tau} = t \quad \text{statistics for the null hypothesis} \quad \phi = 0 \qquad (2)$$

The minimum LM unit root t-statistic determines the endogenous location of two breaks ($\lambda_j = T_{bj}/T, j = 1, 2$). The LM unit root test can endogenously determines two breaks by utilizing a grid search as follows:

$$LMt = \inf_{\lambda} \tilde{\tau}(\lambda) \qquad (3)$$

The data of electricity consumption is obtained from the World Bank's World Development Indicators database. The 23 high income OECD countries considered in this study, for the 1960–2005 period, are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK and US. These countries are selected according to the data availability.

3. Results

Following the study of Lee and Strazicich [8], we determine the number of lagged augmentation terms and start from a maximum of $k = 8$. As such, the procedure looks for the significance of the last augmented term. We then use the 10% asymptotic normal value of 1.645 on the t-statistic of the last first differenced lagged term. After determining the optimal k at each combination of two break points, we determine the structural breaks where the endogenous two breaks LM t-test statistic is at a minimum. We examine each possible combination of two break points over the time interval of [0.1T, 9T] while eliminating the endpoints. Here, T is the sample of size.

We begin with the LM unit root t-statistic with two breaks and examine the significance of the dummy coefficients on the basis of the conventional t-statistics. If less than two breaks are significant at 10%, we apply the minimum LM unit root t-statistic with one break proposed by Lee and Strazicich [9]. The LM unit root test results for per capita electricity consumption series are summarized in Table 1.

The unit root test results shown in Table 1 support the stationarity of the per capita electricity consumption series for the 21 of 23 countries. In other words, shocks to per capita electricity consumption have transitory effects in these 21 countries. However, we are not able to reject the unit root null hypothesis in the cases of Finland and Spain. Table 1 also shows that two structural breaks are significant in the 16 countries and only one structural break exists in other 7 countries (Canada, Finland, Greece, Italy, Japan, Spain, and Switzerland).

Table 1
LM unit roots test results for per capita electricity consumption.

Countries	LM statistics	Breaks
Australia	−5.633 (7)***	1974–1989
Austria	−5.256 (0)***	1971–1992
Belgium	−5.924 (8)***	1970–1988
Canada	−3.830 (8)**	1988
Denmark	−7.983 (8)***	1981–1988
Finland	−2.740 (1)	1978
France	−5.239 (0)***	1977–1988
Germany	−4.776 (8)***	1982–1988
Greece	−3.737 (7)**	1989
Iceland	−5.631 (6)***	1976–1993
Ireland	−4.658 (3)***	1978–1988
Italy	−4.278 (3)***	1974
Japan	−4.238 (6)**	1980
Luxembourg	−6.674 (8)***	1973–1985
Netherlands	−4.730 (8)***	1990–1998
New Zealand	−5.733 (2)***	1976–1985
Norway	−4.741 (3)***	1970–1988
Portugal	−6.618 (6)***	1975–1985
Spain	−3.081 (3)	1980
Sweden	−5.808 (8)***	1978–1985
Switzerland	−5.883 (0)***	1986
UK	−5.253 (7)***	1972–1984
USA	−5.503 (7)***	1980–1999

Notes: Numbers in the parentheses are the optimal number of lagged first-differenced terms included in the unit root test to correct for serial correlation. The 1%, 5% and 10% critical values for the LM test without a break are −3.63, −3.06, and −2.77, respectively. The 1%, 5% and 10% critical values for the minimum LM test with one break are −4.239, −3.566 and −3.211, respectively. The 1%, 5% and 10% critical values for the minimum LM test with two breaks are −4.545, −3.842 and −3.504, respectively. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

An examination of the break points in Table 1 reveals some clustering of the break dates. It is apparent that most structural breaks in the series occur around the crises (notably financial crisis in 1987). This preponderance of break points may reflect recessions during this period which leads to large shifts in the economic activity.

4. Conclusion

We examined the stationary properties of per capita electricity consumption in 23 high income OECD countries by using annual data over 1960–2005. We utilized LM unit root test that endogenously determines breaks in level and trend. According to the unit root test results, we find that 21 country series reject the unit root null hypothesis at the 5% significance level, and accept only in 2 country series (in Finland and Spain). In other words, our empirical findings provide significant evidence that per capita electricity consumption is stationary in almost all countries. Important policy implications emerge from our empirical results of the unit root test with multiple structural breaks. First, if the per capita electricity consumption is mean (or trend) reverting, then it follows that the series will return to its mean value (or trend path) and it might be possible to forecast future movements in the per capita electricity consumption based on past behaviors of the series. Second, as Narayan and Smyth [2] reported, other macroeconomic variables linked to the electricity consumption via flow-on effects will not inherit that non-stationarity condition and transmit it to major economic variables, such as the gross domestic product.

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